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DEC 73 M S WEINSTEIN, D F YOUNG, L A MOLE N00014-72-C-0463

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SUMMARY REPORT

PHASE I

December 27, 1973

Prepared by:

M. S. Weinstein
D. F. Young
L. A. Mole

Sponsored by:

Office of Naval Research/
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13. ABSTRACT

A computer program is described for calculating the signal to noise ratio at the output of vertically directional acoustic arrays in the ocean. The vertical array consists of one to four elements providing an omni-directional and four different types of null patterns. Provision is made for considering other patterns which may be found to be desirable. Multipath transmission is considered in computing signal level. The signal along each path is convolved with the array response for the arrival angle, and the multiple arrivals summed incoherently at the array output. The vertical directionality of the noise is considered and convolved with the array pattern to obtain the noise output. The noise can be partitioned into coherent and incoherent components. Provision is made to investigate the effect of array tilt. The purpose of the study is to compare the S/N ~~the signal to noise~~ ratios for ~~the~~ various environmental conditions to determine the optimum pattern from among the available choices; ~~This~~ this portion of the study has not yet been undertaken.

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Summary Report

Phase I

General

This report summarizes the work performed during the six month period, March through September 1973, under the direction of Code 8109, US Naval Research Laboratory. The effort, designated Phase I, was a continuation of ONR Contract N00014-72-C-0463 and included developing a program for the detailed analysis of vertically directional arrays based on information previously developed under this contract.

Phase I includes the following:

1. Select representative environments and establish the noise and propagation loss parameters.
2. Select the vertical array patterns to be studied; the array will be limited to a maximum of 8 elements.
3. Prepare computer programs to enable evaluation of the conditions for which vertical directivity provides significant advantages.

During the second phase, it is planned that the computer program, that was developed during Phase I, will be used to: (a) compare array configurations, (b) determine the sensitivity of array gains to array

tilt, and (c) to determine the experimental programs for evaluation of the resultant recommendations.

When reviewing the numerical computations, it should be borne in mind that they are included only for the purpose of illustrating the computer model. The directional noise pattern and the propagation loss arrival structure used were those available at the time the computer program was being prepared, and are not matched to represent a realistic combination. Thus, no interpretation is or should be made concerning array performance from the sample tables contained herein.

Selected Environments

Specific representative real world oceanic conditions were selected for determining the propagation loss and the ambient noise. This includes selecting water depths, source and receiver depths and velocity profile.

Propagation Loss

Propagation loss tables were developed for four representative conditions.

Water depths of 17,700, 15,421, 10,000 and 3000 feet were selected. Four geographical areas are represented:

1. North of Mona Passage in the Antillean chain (water depth 17,700 feet)
2. Northeast Pacific (water depth 15,421 feet)
3. Gulf of Mexico (water depth 10,000 feet)
4. Off east coast of Florida (water depth 3,000 feet)

The critical depths and the source and receiver depths are shown in Table 1. All predictions were made for a frequency of 100 Hz.

The first two cases, with water depths of 17,700 feet and 15,421 feet, have the hydrophone depths ranging from on the bottom to a receiving depth somewhat less than critical depth. The source depth of 60 feet was kept constant, representing a shallow source.

The remaining two cases, with water depths of 10,000, and 3,000 feet, were selected so that the water depth would be shallower than critical depth, so that there

would be no depth excess. For these two cases, the hydrophones were placed at two depths: on the bottom and 500 feet above the bottom. The source depth was also at 60 feet for these Propagation loss calculations.

Propagation loss tables have been prepared for all of the cases listed in Table 1. The propagation loss tables include the loss and the arrival angle for each path. Losses for signals arriving via bottom paths were computed using bottom loss tables based on curves given in Ref. (1). The computations were made in 2 n.m. steps out to 50 n.m. or until the propagation loss exceeded 120 db. A typical case is shown in Table 2.

Noise

The vertical directionality of the noise field is not well known. At low frequencies the noise field peaks in the horizontal or near horizontal direction. Above critical depth, with appropriate environmental conditions, a noise hole may exist in the horizontal direction with maxima located at angles to $\pm 15^{\circ}$ to the horizontal. Alternatively, because of bottom

topography, or variations in the sound velocity profile and the distribution of surface shipping, the noise hole may be filled.

In order to investigate all possibilities, a series of generic vertical noise distributions were selected for investigation. The primary goal is to determine the dependence of system performance on different noise distributions for various array patterns. A typical set of noise patterns is shown in Figure (1). In addition, the program includes the capability of adding some incoherent noise energy so that its effects can be observed.

Array Directivity Pattern

The array patterns that are considered are listed below. These were selected to provide suppression of horizontal or near horizontal noise. The potential detection range is limited to a maximum of 50 n.m. via bottom bounce paths and the RAP path for direct arrivals.

1. Single omni-directional hydrophones.
2. Two hydrophone arrays (dipole) with a null in the horizontal direction, or a null in the direction of $+\theta^{\circ}$ or $-\theta^{\circ}$.

3. Three hydrophone arrays with nulls at $\pm\theta^{\circ}$ relative to the horizontal.

4. Four hydrophone array with nulls at $\pm\theta^{\circ}$, and 0° to the horizontal.

It is planned that during Phase II, each of these patterns will be tested against selected combinations of noise patterns and signal arrival patterns. The purpose is to determine the improvement achieved as the number of hydrophones increases.

Arrays with more than four elements have not been considered.

Computer Program

The computer program has been written in sections so that modifications, such as array configurations, could be accomplished without re-writing the whole program. The following paragraphs provide a brief summary of the steps followed in computing the array calculations.

1. The noise directionality pattern is digitized and entered into the computer. The noise field is numerically integrated using incremental angles of one degree and an omnidirectional pattern. Any incoherent noise is entered and summed with the directional noise. The total noise field is then arbitrarily fixed at

-20 db, independent of the shape of the noise pattern. This is done to ensure that computations conducted for different noise patterns are not affected by variations in the absolute level.

2. The array patterns are selected and the array directivity computed. The computation is frequency independent, and is based on the ratio of wave length to receiving element separation. A typical computer printout is shown in Table 3.

3. The array patterns and the noise field are subsequently combined taking into account:

   a. Partition between coherent and incoherent energy.

   b. Array tilt.

The array output level is determined and printed out. Typical printouts for a set of array directivity patterns are shown in Table 4.

4. Data from the propagation loss table is entered into the computer. The source level is fixed at 60 db. The

signal along each path is combined with the array pattern to determine the array output. The array output for each of the paths is energy summed to determine total array output. It is assumed that the signal is totally coherent along each path. The arrivals over different paths are combined as if they are uncorrelated. (Note: this neglects fluctuations due to phase relationships as the target moves along the track, and uses an average propagation loss value.) The total signal is printed out, as shown in Table 5.

Array tilt can be accommodated by assigning the plane of tilt, and the relative signal direction. The signal arrival angles, Table 2, are then shifted by the appropriate amount and combined with the untilted array directivity patterns.

5. The signal level and noise level are combined and the signal-to-noise ratio printed out in 2 n.m. increments. Typical results are also shown in Table 5.

Summary

All segments of the computer program have been checked out by inserting preliminary data. The program has been developed to the point where the array comparisons can be performed and the results analyzed for those parameters considered. If other arrays factors are considered, such as use of difar elements, a subroutine can be written to accommodate the computations.

TABLE 1

PERTINENT PROPAGATION LOSS TABLE PARAMETERS

Water Depth (ft)	Critical Depth (ft)	Source Depth (ft)	Receiver Depth (ft)
17700	14528	60	13500
17700	14528	60	14528
17700	14528	60	16200
17700	14528	60	17500
17700	14528	60	17700
15421	11491	60	10500
15421	11491	60	11491
15421	11491	60	13200
15421	11491	60	14921
15421	11491	60	15421
10000	-	60	9500
10000	-	60	10000
3000	-	60	2500
3000	-	60	3000

TABLE 2

SAMPLE PROPAGATION LOSS TABLE

FREQ 100 Hz, SOURCE DEPTH 60 FT., RECEIVER DEPTH 10500 FT., WATER DEPTH 15421 FT.

Range (n.m.)	D&SR		1BB				2BB				3BB			
	θ_R	PL	θ_R	PL	θ_R	PL	θ_R	PL	θ_R	PL	θ_R	PL	θ_R	PL
0	+90	68	-90	82	+90	88	-90	98	+90	101	-90	110	+90	112
2	+40	72	-59	83	+74	88	-77	98	+81	101	-82	110	+83	112
4	+21	76	-40	83	+59	89	-65	99	+71	101	-74	110	+77	112
6	+13	79	-29	83	+48	89	-55	100	+63	102	-66	111	+71	112
8	+ 8	81	-22	82	+40	89	-47	98	+56	102	-59	111	+65	113
10	+ 5	83	-18	84	+34	89	-40	95	+50	101	-53	111	+59	113
12			-15	85	+29	89	-35	94	+44	100	-48	109	+54	114
14			-14	86	+25	89	-31	93	+40	99	-44	107	+50	111
16			-12	87	+22	88	-28	92	+36	99	-40	104	+46	109
18			-11	88	+20	89	-25	93	+33	98	-36	105	+43	109
20			-11	89	+18	90	-23	90	+30	97	-34	103	+40	107
22			-10	90	+16	90	-21	91	+28	95	-31	100	+37	107
24			-10	91	+15	91	-19	91	+25	96	-29	101	+35	105
26					+13	92	-18	92	+23	94	-27	98	+32	105
28					+12	92	-16	92	+22	93	-26	99	+30	102
30					+12	93	-15	93	+21	93	-24	96	+29	103
32					+11	93	-14	94	+19	94	-23	94	+27	100
34					+11	94	-14	94	+18	94	-21	94	+26	101
36					+10	94	-13	94	+17	95	-20	95	+24	98
38					+10	95	-12	95	+16	95	-19	95	+23	98
40							-12	95	+15	96	-18	96	+22	96
42							-11	96	+15	96	-17	96	+21	96
44							-11	96	+14	96	-16	96	+20	97
46							-11	97	+13	97	-16	97	+19	97
48							-11	97	+13	97	-15	97	+18	97
50							-10	97	+12	97	-15	97	+17	98

NOTE: In most cases arrivals of a particular propagation type have been grouped together when the receiver angles and losses along the paths are essentially the same.

TABLE 2 (CONT'D)

Range (n.m.)	4BB				5BB				6BB			
	θ_R	PL	θ_R	PL	θ_R	PL	θ_R	PL	θ_R	PL	θ_R	PL
0												
2												
4												
6												
8												
10												
12												
14												
16												
18	-46	115	+51	120								
20	-43	116	+48	121								
22	-40	112	+45	117								
24	-37	113	+42	117								
26	-35	109	+40	114								
28	-33	109	+38	114	-40	119	+44	125				
30	-32	106	+36	115	-37	120	+42	125				
32	-30	106	+34	111	-36	120	+40	121				
34	-28	103	+32	111	-34	115	+38	121				
36	-27	103	+31	108	-32	116	+36	121				
38	-26	103	+30	108	-32	111	+35	116				
40	-24	100	+29	108	-31	111	+33	117				
42	-23	100	+27	105	-29	112	+32	117				
44	-22	97	+26	105	-28	107	+31	112	-32	121	+35	122
46	-21	97	+25	105	-27	107	+30	113	-32	116	+34	122
48	-21	97	+24	102	-26	108	+29	113	-31	116	+33	122
50	-20	98	+23	102	-25	108	+28	108	-30	116	+32	123

TABLE 2 (CONT'D)

Range (n.m.)	RSR		RRR		RRR		RRR	
	θ_R	PL	θ_R	PL	θ_R	PL	θ_R	PL
0								
2								
4								
6								
8								
10								
12			+2	81				
14					0	85	0	85
16					-3	87	-2	87
18					-4	88	-4	88
20	-6	89						
22	-8	90						
24	-9	91						
26								
28								
30								
32								
34								
36								
38								
40			+1	85				
42					-1	91	-1	91
44					-3	93	-3	93
46					-4	94	-4	94
48	-5	97						
50	-7	97						

Table 3

G (011001) 10001,
DIRECTIVITY PATTERNS OF 20 LOG P

CONSTANTS:
DELAY ANGLE = 0010.00 DEG.
LAMBDA = 0001.00 FT.
ELEM. SEP. = 0000.30 FT.

ARRAYS:
A = FOUR ELEMENT
B = THREE ELEMENT
C = TWO ELEMENT-WITH DELAY
D = TWO ELEMENT-NO DELAY

ANGLE	A	B	C	D
-0090.00	0012.14	0007.97	0005.03	0004.16
-0089.00	0012.13	0007.97	0005.03	0004.16
-0088.00	0012.12	0007.95	0005.02	0004.16
-0087.00	0012.12	0007.95	0005.02	0004.16
-0086.00	0012.10	0007.95	0005.03	0004.15
-0085.00	0012.07	0007.92	0005.02	0004.14
-0084.00	0012.03	0007.90	0005.00	0004.13
-0083.00	0012.00	0007.88	0005.00	0004.11
-0082.00	0011.97	0007.86	0005.00	0004.11
-0081.00	0011.90	0007.81	0004.98	0004.09
-0080.00	0011.86	0007.78	0004.96	0004.07
-0079.00	0011.80	0007.75	0004.95	0004.05
-0078.00	0011.74	0007.70	0004.94	0004.03
-0077.00	0011.66	0007.65	0004.92	0004.01
-0076.00	0011.58	0007.59	0004.90	0003.98
-0075.00	0011.51	0007.55	0004.89	0003.96
-0074.00	0011.40	0007.47	0004.86	0003.93
-0073.00	0011.31	0007.41	0004.84	0003.89
-0072.00	0011.20	0007.34	0004.82	0003.85
-0071.00	0011.08	0007.26	0004.79	0003.82
-0070.00	0010.97	0007.18	0004.76	0003.79
-0069.00	0010.84	0007.09	0004.73	0003.74
-0068.00	0010.71	0007.01	0004.71	0003.70
-0067.00	0010.56	0006.90	0004.67	0003.65
-0066.00	0010.42	0006.81	0004.64	0003.61
-0065.00	0010.26	0006.70	0004.61	0003.55
-0064.00	0010.08	0006.57	0004.56	0003.50
-0063.00	0009.91	0006.47	0004.52	0003.44
-0062.00	0009.72	0006.33	0004.47	0003.38
-0061.00	0009.54	0006.22	0004.44	0003.32
-0060.00	0009.33	0006.07	0004.39	0003.25
-0059.00	0009.12	0005.93	0004.34	0003.19
-0058.00	0008.89	0005.77	0004.28	0003.12
-0057.00	0008.66	0005.61	0004.23	0003.04

Table 3 (Continued)

0116.01				
-0056.00	0008.41	0005.45	0004.17	0002.96
-0055.00	0008.17	0005.28	0004.12	0002.88
-0054.00	0007.89	0005.09	0004.06	0002.79
-0053.00	0007.61	0004.90	0003.99	0002.70
-0052.00	0007.32	0004.71	0003.93	0002.60
-0051.00	0007.01	0004.49	0003.85	0002.51
-0050.00	0006.70	0004.29	0003.79	0002.41
-0049.00	0006.36	0004.05	0003.71	0002.31
-0048.00	0006.01	0003.81	0003.62	0002.19
-0047.00	0005.65	0003.57	0003.55	0002.08
-0046.00	0005.25	0003.29	0003.46	0001.96
-0045.00	0004.87	0003.03	0003.37	0001.83
-0044.00	0004.46	0002.75	0003.28	0001.70
-0043.00	0004.03	0002.46	0003.18	0001.56
-0042.00	0003.59	0002.16	0003.08	0001.42
-0041.00	0003.10	0001.82	0002.96	0001.27
-0040.00	0002.62	0001.50	0002.86	0001.12
-0039.00	0002.10	0001.14	0002.74	0000.96
-0038.00	0001.56	0000.77	0002.62	0000.79
-0037.00	0001.01	0000.39	0002.50	0000.62
-0036.00	0000.42	-0000.00	0002.36	0000.43
-0035.00	-0000.18	-0000.42	0002.24	0000.24
-0034.00	-0000.82	-0000.86	0002.10	0000.04
-0033.00	-0001.50	-0001.33	0001.95	-0000.16
-0032.00	-0002.22	-0001.83	0001.79	-0000.39
-0031.00	-0002.96	-0002.34	0001.64	-0000.61
-0030.00	-0003.72	-0002.88	0001.47	-0000.84
-0029.00	-0004.55	-0003.45	0001.30	-0001.09
-0028.00	-0005.42	-0004.06	0001.12	-0001.35
-0027.00	-0006.33	-0004.70	0000.94	-0001.63
-0026.00	-0007.30	-0005.38	0000.75	-0001.91
-0025.00	-0008.34	-0006.11	0000.54	-0002.22
-0024.00	-0009.41	-0006.88	0000.33	-0002.52
-0023.00	-0010.57	-0007.71	0000.12	-0002.86
-0022.00	-0011.82	-0008.61	-0000.12	-0003.21
-0021.00	-0013.15	-0009.57	-0000.35	-0003.58
-0020.00	-0014.59	-0010.62	-0000.61	-0003.96
-0019.00	-0016.14	-0011.76	-0000.86	-0004.38
-0018.00	-0017.85	-0013.03	-0001.14	-0004.82
-0017.00	-0019.73	-0014.44	-0001.41	-0005.28
-0016.00	-0021.85	-0016.06	-0001.71	-0005.78
-0015.00	-0024.25	-0017.92	-0002.02	-0006.32
-0014.00	-0027.08	-0020.17	-0002.35	-0006.91
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-0011.00	-0042.19	-0033.24	-0003.44	-0008.94
-0010.00	-0362.77	-0353.02	-0003.83	-0009.74
-0009.00	-0044.69	-0034.04	-0004.26	-0010.64
-0008.00	-0040.12	-0028.46	-0004.71	-0011.65
-0007.00	-0038.24	-0025.42	-0005.20	-0012.81
-0006.00	-0037.56	-0023.42	-0005.71	-0014.14
-0005.00	-0037.75	-0022.05	-0006.28	-0015.70
-0004.00	-0038.67	-0021.04	-0006.86	-0017.63
-0003.00	-0040.48	-0020.34	-0007.68	-0020.13
-0002.00	-0043.50	-0019.85	-0008.17	-0023.64
-0001.00	-0049.23	-0019.57	-0008.92	-0029.66

Table 3 (Continued)

0116.02

0000.00	-0368.68	-0019.49	-0009.74	-0349.18
0001.00	-0049.23	-0019.57	-0010.65	-0029.66
0002.00	-0043.50	-0019.85	-0011.67	-0023.64
0003.00	-0040.48	-0020.34	-0012.35	-0020.13
0004.00	-0038.67	-0021.04	-0014.18	-0017.63
0005.00	-0037.75	-0022.05	-0015.76	-0015.70
0006.00	-0037.56	-0023.42	-0017.71	-0014.14
0007.00	-0038.24	-0025.42	-0020.22	-0012.81
0008.00	-0040.12	-0028.46	-0023.74	-0011.65
0009.00	-0044.69	-0034.04	-0029.78	-0010.64
0010.00	-0362.77	-0353.02	-0349.18	-0009.74
0011.00	-0042.19	-0033.24	-0029.80	-0008.94
0012.00	-0035.06	-0026.86	-0023.80	-0008.20
0013.00	-0030.54	-0023.01	-0020.30	-0007.53
0014.00	-0027.08	-0020.17	-0017.81	-0006.91
0015.00	-0024.25	-0017.92	-0015.90	-0006.32
0016.00	-0021.85	-0016.06	-0014.34	-0005.78
0017.00	-0019.73	-0014.44	-0013.03	-0005.28
0018.00	-0017.85	-0013.03	-0011.88	-0004.82
0019.00	-0016.14	-0011.76	-0010.89	-0004.38
0020.00	-0014.59	-0010.62	-0010.00	-0003.96
0021.00	-0013.15	-0009.57	-0009.21	-0003.58
0022.00	-0011.82	-0008.61	-0008.48	-0003.21
0023.00	-0010.57	-0007.71	-0007.83	-0002.86
0024.00	-0009.41	-0006.88	-0007.22	-0002.52
0025.00	-0008.34	-0006.11	-0006.66	-0002.22
0026.00	-0007.30	-0005.38	-0006.13	-0001.91
0027.00	-0006.33	-0004.70	-0005.64	-0001.63
0028.00	-0005.42	-0004.06	-0005.19	-0001.35
0029.00	-0004.55	-0003.45	-0004.76	-0001.09
0030.00	-0003.72	-0002.88	-0004.36	-0000.84
0031.00	-0002.96	-0002.34	-0003.98	-0000.61
0032.00	-0002.22	-0001.83	-0003.62	-0000.39
0033.00	-0001.50	-0001.33	-0003.29	-0000.16
0034.00	-0000.82	-0000.86	-0002.96	0000.04
0035.00	-0000.18	-0000.42	-0002.67	0000.24
0036.00	0000.42	-0000.00	-0002.37	0000.43
0037.00	0001.01	0000.39	-0002.10	0000.62
0038.00	0001.56	0000.77	-0001.85	0000.79
0039.00	0002.10	0001.14	-0001.59	0000.96
0040.00	0002.62	0001.50	-0001.35	0001.12
0041.00	0003.10	0001.82	-0001.14	0001.27
0042.00	0003.59	0002.16	-0000.91	0001.42
0043.00	0004.03	0002.46	-0000.71	0001.56
0044.00	0004.46	0002.75	-0000.52	0001.70
0045.00	0004.87	0003.03	-0000.33	0001.83
0046.00	0005.25	0003.29	-0000.16	0001.96
0047.00	0005.65	0003.57	0000.02	0002.08
0048.00	0006.01	0003.81	0000.18	0002.19
0049.00	0006.36	0004.05	0000.34	0002.31
0050.00	0006.70	0004.29	0000.49	0002.41
0051.00	0007.01	0004.49	0000.64	0002.51
0052.00	0007.32	0004.71	0000.77	0002.60
0053.00	0007.61	0004.90	0000.90	0002.70
0054.00	0007.89	0005.09	0001.03	0002.79
0055.00	0008.17	0005.28	0001.15	0002.88

Table 3 (Continued)

0116.03

0056.00	0008.41	0005.45	0001.27	0002.96
0057.00	0008.66	0005.61	0001.37	0003.04
0058.00	0008.89	0005.77	0001.48	0003.12
0059.00	0009.12	0005.93	0001.58	0003.19
0060.00	0009.33	0006.07	0001.68	0003.25
0061.00	0009.54	0006.22	0001.77	0003.32
0062.00	0009.72	0006.33	0001.85	0003.38
0063.00	0009.91	0006.47	0001.94	0003.44
0064.00	0010.08	0006.57	0002.01	0003.50
0065.00	0010.26	0006.70	0002.09	0003.55
0066.00	0010.42	0006.81	0002.16	0003.61
0067.00	0010.56	0006.90	0002.23	0003.65
0068.00	0010.71	0007.01	0002.29	0003.70
0069.00	0010.84	0007.09	0002.35	0003.74
0070.00	0010.97	0007.18	0002.41	0003.79
0071.00	0011.08	0007.26	0002.46	0003.82
0072.00	0011.20	0007.34	0002.52	0003.85
0073.00	0011.31	0007.41	0002.56	0003.89
0074.00	0011.40	0007.47	0002.60	0003.93
0075.00	0011.51	0007.55	0002.65	0003.96
0076.00	0011.58	0007.59	0002.69	0003.98
0077.00	0011.66	0007.65	0002.72	0004.01
0078.00	0011.74	0007.70	0002.76	0004.03
0079.00	0011.80	0007.75	0002.79	0004.05
0080.00	0011.86	0007.78	0002.81	0004.07
0081.00	0011.90	0007.81	0002.83	0004.09
0082.00	0011.97	0007.86	0002.86	0004.11
0083.00	0012.00	0007.88	0002.88	0004.11
0084.00	0012.03	0007.90	0002.90	0004.13
0085.00	0012.07	0007.92	0002.90	0004.14
0086.00	0012.10	0007.95	0002.92	0004.15
0087.00	0012.12	0007.95	0002.93	0004.16
0088.00	0012.12	0007.95	0002.93	0004.16
0089.00	0012.13	0007.97	0002.93	0004.16
0090.00	0012.14	0007.97	0002.94	0004.16

Table 4

G (010001) ,

ARRAY NOISE LEVELS

DIRECTIVITY PATTERN #:	0116
CORRECTED NOISE FIELD #:	0001
THE ARRAY TILT ANGLE (DEGS):	0000
THE INCOHERENT NOISE LEVEL (DB):	-0200.00

THE CALCULATED NOISE LEVELS IN DB ARE:

	COHERENT	TOTAL
FOUR ELEMENT:	-0043.33	-0043.33
THREE ELEMENT:	-0041.55	-0041.55
TWO ELEMENT-WITH DELAY:	-0027.14	-0027.14
TWO ELEMENT-NO DELAY:	-0029.98	-0029.98
OMNI-DIRECTIONAL:	-0020.01	-0020.01

Table 4 (Continued)

G (010001) ,

ARRAY NOISE LEVELS

DIRECTIVITY PATTERN #:	0116
CORRECTED NOISE FIELD #:	0001
THE ARRAY TILT ANGLE (DEGS):	0005
THE INCOHERENT NOISE LEVEL (DB):	-0200.00

THE CALCULATED NOISE LEVELS IN DB ARE:

	COHERENT	TOTAL
FOUR ELEMENT:	-0042.51	-0042.51
THREE ELEMENT:	-0039.92	-0039.92
TWO ELEMENT-WITH DELAY:	-0026.98	-0026.98
TWO ELEMENT-NO DELAY:	-0029.66	-0029.66
OMNI-DIRECTIONAL:	-0020.01	-0020.01

Table 4 (Continued)

G (010001) ,

ARRAY NOISE LEVELS

DIRECTIVITY PATTERN #:	0116
CORRECTED NOISE FIELD #:	0003
THE ARRAY TILT ANGLE (DEGS):	0000
THE INCOHERENT NOISE LEVEL (DB):	-0030.41

THE CALCULATED NOISE LEVELS IN DB ARE:

	COHERENT	TOTAL
FOUR ELEMENT:	-0043.75	-0024.36
THREE ELEMENT:	-0041.96	-0025.55
TWO ELEMENT-WITH DELAY:	-0027.55	-0024.46
TWO ELEMENT-NO DELAY:	-0030.40	-0025.63
OMNI-DIRECTIONAL:	-0020.42	-0020.01

Table 4 (Continued)

G (010001) ,

ARRAY NOISE LEVELS

DIRECTIVITY PATTERN #:	0116
CORRECTED NOISE FIELD #:	0003
THE ARRAY TILT ANGLE (DEGS):	0005
THE INCOHERENT NOISE LEVEL (DB):	-0030.41

THE CALCULATED NOISE LEVELS IN DB ARE:

	COHERENT	TOTAL
FOUR ELEMENT:	-0042.92	-0024.34
THREE ELEMENT:	-0040.34	-0025.50
TWO ELEMENT-WITH DELAY:	-0027.39	-0024.39
TWO ELEMENT-NO DELAY:	-0030.08	-0025.53
OMNI-DIRECTIONAL:	-0020.42	-0020.01

Table 5

BOTTOM VERTICAL
ARRAY PERFORMANCE

SYSTEM PARAMETERS

ARRAY SIZE:	FOUR EL.	
SOURCE LEVEL VALUE:	0060.00	DB
LOSS TABLE #:	0001	
NET NOISE FIELD #:	0001	
ARRAY PATTERN #:	0116	
DELAY ANGLE:	0010.00	DEG
SEPARATION:	0000.30	FT
LAMBDA:	0001.00	FT
EFFECTIVE NOISE LEVEL:	-0043.33	DB

RANGE NM.	S/N DB.	SIGNAL LEVEL DB.
0050	-0014.36	-0057.70
0048	-0013.59	-0056.92
0046	-0011.59	-0054.93
0044	-0010.10	-0053.44
0042	-0010.69	-0054.03
0040	-0009.25	-0052.59
0038	-0008.79	-0052.13
0036	-0008.58	-0051.92
0034	-0005.75	-0049.09
0032	-0005.27	-0048.61
0030	-0004.37	-0047.71
0028	-0003.62	-0046.96
0026	-0002.90	-0046.24
0024	-0000.18	-0043.52
0022	0000.23	-0043.10
0020	0002.40	-0040.93
0018	0004.65	-0038.68
0016	0006.78	-0036.55
0014	0010.05	-0033.28
0012	0012.13	-0031.20
0010	0014.18	-0029.15
0008	0016.09	-0027.24
0006	0019.53	-0023.80
0004	0027.57	-0015.76
0002	0038.06	-0005.27
0000	0043.81	0000.47

Table 5 (Continued)

BOTTOM VERTICAL
ARRAY PERFORMANCE

SYSTEM PARAMETERS

ARRAY SIZE:	THREE EL.	
SOURCE LEVEL VALUE:	0060.00	DB
LOSS TABLE #:	0001	
NET NOISE FIELD #:	0001	
ARRAY PATTERN #:	0116	
DELAY ANGLE:	0010.00	DEG
SEPARATION:	0000.30	FT
LAMBDA:	0001.00	FT
EFFECTIVE NOISE LEVEL:	-0041.55	DB

RANGE NM.	S/N DB.	SIGNAL LEVEL DB.
0050	-0009.36	-0050.92
0048	-0009.00	-0050.56
0046	-0007.68	-0049.24
0044	-0006.69	-0048.25
0042	-0007.66	-0049.22
0040	-0006.79	-0048.35
0038	-0006.45	-0048.01
0036	-0007.00	-0048.56
0034	-0004.78	-0046.34
0032	-0004.48	-0046.04
0030	-0004.18	-0045.74
0028	-0003.06	-0044.62
0026	-0002.27	-0043.83
0024	0000.14	-0041.41
0022	0000.36	-0041.19
0020	0002.43	-0039.12
0018	0004.84	-0036.71
0016	0006.44	-0035.11
0014	0008.78	-0032.77
0012	0010.07	-0031.48
0010	0011.24	-0030.31
0008	0013.00	-0028.55
0006	0017.69	-0023.86
0004	0025.08	-0016.47
0002	0033.36	-0008.19
0000	0037.86	-0003.69

Table 5 (Continued)

BOTTOM VERTICAL
ARRAY PERFORMANCE

SYSTEM PARAMETERS

ARRAY SIZE:	TWO EL. VD	
SOURCE LEVEL VALUE:	0060.00	DB
LOSS TABLE #:	0001	
NET NOISE FIELD #:	0001	
ARRAY PATTERN #:	0116	
DELAY ANGLE:	0010.00	DEG
SEPARATION:	0000.30	FT
LAMBDA:	0001.00	FT
EFFECTIVE NOISE LEVEL:	-0027.14	DB

RANGE NM.	S/N DB.	SIGNAL LEVEL DB.
0050	-0010.82	-0037.97
0048	-0012.26	-0039.41
0046	-0011.02	-0038.17
0044	-0010.78	-0037.93
0042	-0012.02	-0039.17
0040	-0011.06	-0038.20
0038	-0010.49	-0037.64
0036	-0010.30	-0037.45
0034	-0009.50	-0036.65
0032	-0008.50	-0035.65
0030	-0008.19	-0035.34
0028	-0008.52	-0035.67
0026	-0008.14	-0035.29
0024	-0008.06	-0035.21
0022	-0009.27	-0036.42
0020	-0007.81	-0034.96
0018	-0004.17	-0031.32
0016	-0003.28	-0030.43
0014	-0001.74	-0028.89
0012	-0000.33	-0027.46
0010	0001.98	-0025.16
0008	0002.73	-0024.41
0006	0005.32	-0021.82
0004	0009.63	-0017.51
0002	0015.17	-0011.97
0000	0018.61	-0008.53

Table 5 (Continued)

BOTTOM VERTICAL
ARRAY PERFORMANCE

SYSTEM PARAMETERS

ARRAY SIZE:	TWO EL. ND	
SOURCE LEVEL VALUE:	0060.00	DB
LOSS TABLE #:	0001	
NET NOISE FIELD #:	0001	
ARRAY PATTERN #:	0116	
DELAY ANGLE:	0010.00	DEG
SEPARATION:	0000.30	FT
LAMBDA:	0001.00	FT
EFFECTIVE NOISE LEVEL:	-0029.98	DB

RANGE NM.	S/N DB.	SIGNAL LEVEL DB.
0050	-0011.13	-0041.12
0048	-0012.21	-0042.20
0046	-0010.71	-0040.70
0044	-0010.23	-0040.22
0042	-0011.58	-0041.57
0040	-0010.66	-0040.65
0038	-0009.68	-0039.67
0036	-0009.71	-0039.70
0034	-0008.39	-0038.38
0032	-0007.38	-0037.37
0030	-0006.51	-0036.50
0028	-0006.42	-0036.41
0026	-0005.87	-0035.86
0024	-0005.09	-0035.08
0022	-0005.76	-0035.75
0020	-0004.29	-0034.28
0018	-0003.71	-0033.70
0016	-0002.72	-0032.71
0014	-0000.44	-0030.43
0012	0001.21	-0028.76
0010	0003.66	-0026.32
0008	0005.52	-0024.46
0006	0009.16	-0020.82
0004	0014.07	-0015.91
0002	0019.37	-0010.61
0000	0022.48	-0007.50

Table 5 (Continued)

BOTTOM VERTICAL
ARRAY PERFORMANCE

SYSTEM PARAMETERS

ARRAY SIZE:	1 OMNI-HYD	
SOURCE LEVEL VALUE:	0060.00	DB
LOSS TABLE #:	0001	
NET NOISE FIELD #:	0001	
ARRAY PATTERN #:	0116	
DELAY ANGLE:	0010.00	DEG
SEPARATION:	0000.30	FT
LAMBDA:	0001.00	FT
EFFECTIVE NOISE LEVEL:	-0020.00	DB

RANGE NM.	S/N DB.	SIGNAL LEVEL DB.
0050	-0010.81	-0030.81
0048	-0011.77	-0031.77
0046	-0010.83	-0030.83
0044	-0010.83	-0030.83
0042	-0011.63	-0031.63
0040	-0010.88	-0030.88
0038	-0010.75	-0030.75
0036	-0010.33	-0030.33
0034	-0010.18	-0030.18
0032	-0009.37	-0029.37
0030	-0009.60	-0029.60
0028	-0009.95	-0029.95
0026	-0010.15	-0030.15
0024	-0010.45	-0030.45
0022	-0011.88	-0031.88
0020	-0011.02	-0031.02
0018	-0004.07	-0024.07
0016	-0003.32	-0023.32
0014	-0002.32	-0022.32
0012	-0001.47	-0021.47
0010	0000.25	-0019.74
0008	0000.30	-0019.69
0006	0001.58	-0018.41
0004	0003.87	-0016.12
0002	0006.46	-0013.53
0000	0008.33	-0011.66

Table 5 (Continued)

S (01-736) ,

BOTTOM VERTICAL
ARRAY PERFORMANCE

SYSTEM PARAMETERS

ARRAY SIZE:	FOUR EL.	
SOURCE LEVEL VALUE:	0060.00	DB
LOSS TABLE #:	0001	
NET NOISE FIELD #:	0003	
ARRAY PATTERN #:	0116	
DELAY ANGLE:	0010.00	DEG
SEPARATION:	0000.30	FT
LAMBDA:	0001.00	FT

EFFECTIVE NOISE LEVEL: -0024.35 DB

RANGE NM.	S/N DB.	SIGNAL LEVEL DB.
0050	-0033.34	-0057.70
0048	-0032.56	-0056.92
0046	-0030.57	-0054.93
0044	-0029.08	-0053.44
0042	-0029.67	-0054.03
0040	-0028.23	-0052.59
0038	-0027.77	-0052.13
0036	-0027.56	-0051.92
0034	-0024.73	-0049.09
0032	-0024.25	-0048.61
0030	-0023.35	-0047.71
0028	-0022.60	-0046.96
0026	-0021.88	-0046.24
0024	-0019.16	-0043.52
0022	-0018.73	-0043.10
0020	-0016.57	-0040.93
0018	-0014.32	-0038.68
0016	-0012.19	-0036.55
0014	-0008.91	-0033.28
0012	-0006.84	-0031.20
0010	-0004.79	-0029.15
0008	-0002.87	-0027.24
0006	0000.85	-0023.50
0004	0008.59	-0015.76
0002	0019.08	-0005.27
0000	0024.83	0000.47

Table 5 (Continued)

BOTTOM VERTICAL
ARRAY PERFORMANCE

SYSTEM PARAMETERS

ARRAY SIZE:	THREE EL.	
SOURCE LEVEL VALUE:	0060.00	DB
LOSS TABLE #:	0001	
NET NOISE FIELD #:	0003	
ARRAY PATTERN #:	0116	
DELAY ANGLE:	0010.00	DEG
SEPARATION:	0000.30	FT
LAMBDA:	0001.00	FT
EFFECTIVE NOISE LEVEL:	-0025.54	DB

RANGE NM.	S/N DB.	SIGNAL LEVEL DB.
0050	-0025.37	-0050.92
0048	-0025.01	-0050.56
0046	-0023.69	-0049.24
0044	-0022.70	-0048.25
0042	-0023.67	-0049.22
0040	-0022.80	-0048.35
0038	-0022.46	-0048.01
0036	-0023.01	-0048.56
0034	-0020.79	-0046.34
0032	-0020.49	-0046.04
0030	-0020.19	-0045.74
0028	-0019.07	-0044.62
0026	-0018.28	-0043.83
0024	-0015.86	-0041.41
0022	-0015.64	-0041.19
0020	-0013.57	-0039.12
0018	-0011.16	-0036.71
0016	-0009.56	-0035.11
0014	-0007.22	-0032.77
0012	-0005.93	-0031.48
0010	-0004.76	-0030.31
0008	-0003.00	-0028.55
0006	0001.68	-0023.86
0004	0009.07	-0016.47
0002	0017.35	-0008.19
0000	0021.85	-0003.69

Table 5 (Continued)

BOTTOM VERTICAL
ARRAY PERFORMANCE

SYSTEM PARAMETERS

ARRAY SIZE:	TWO EL. WD	
SOURCE LEVEL VALUE:	0060.00	DB
LOSS TABLE #:	0001	
NET NOISE FIELD #:	0003	
ARRAY PATTERN #:	0116	
DELAY ANGLE:	0010.00	DEG
SEPARATION:	0000.30	FT
LAMBDA:	0001.00	FT

EFFECTIVE NOISE LEVEL: -0024.45 DB

RANGE NM.	S/N DB.	SIGNAL LEVEL DB.
0050	-0013.51	-0037.97
0048	-0014.95	-0039.41
0046	-0013.71	-0038.17
0044	-0013.47	-0037.93
0042	-0014.71	-0039.17
0040	-0013.74	-0038.20
0038	-0013.18	-0037.64
0036	-0012.99	-0037.45
0034	-0012.22	-0036.68
0032	-0011.19	-0035.65
0030	-0010.88	-0035.34
0028	-0011.21	-0035.67
0026	-0010.83	-0035.29
0024	-0010.75	-0035.21
0022	-0011.96	-0036.42
0020	-0010.50	-0034.96
0018	-0006.86	-0031.32
0016	-0005.97	-0030.43
0014	-0004.43	-0028.89
0012	-0003.02	-0027.48
0010	-0000.70	-0025.16
0008	0000.04	-0024.41
0006	0002.63	-0021.82
0004	0006.94	-0017.51
0002	0012.48	-0011.97
0000	0015.92	-0008.53

Table 5 (Continued)

BOTTOM VERTICAL
ARRAY PERFORMANCE

SYSTEM PARAMETERS

ARRAY SIZE:	TWO EL.	ND
SOURCE LEVEL VALUE:	0060.00	DB
LOSS TABLE #:	0001	
NET NOISE FIELD #:	0003	
ARRAY PATTERN #:	0116	
DELAY ANGLE:	0010.00	DEG
SEPARATION:	0000.30	FT
LAMBDA:	0001.00	FT
EFFECTIVE NOISE LEVEL:	-0025.62	DB

RANGE NM.	S/N DB.	SIGNAL LEVEL DB.
0050	-0015.49	-0041.12
0048	-0016.57	-0042.20
0046	-0015.07	-0040.70
0044	-0014.59	-0040.22
0042	-0015.94	-0041.57
0040	-0015.02	-0040.65
0038	-0014.04	-0039.67
0036	-0014.07	-0039.70
0034	-0012.75	-0038.38
0032	-0011.74	-0037.37
0030	-0011.18	-0036.80
0028	-0010.78	-0036.41
0026	-0010.23	-0035.86
0024	-0009.45	-0035.08
0022	-0010.12	-0035.75
0020	-0008.65	-0034.28
0018	-0008.07	-0033.70
0016	-0007.08	-0032.71
0014	-0004.80	-0030.43
0012	-0003.13	-0028.76
0010	-0000.69	-0026.32
0008	0001.16	-0024.46
0006	0004.80	-0020.82
0004	0009.71	-0015.91
0002	0015.01	-0010.61
0000	0018.12	-0007.50

Table 5 (Continued)

BOTTOM VERTICAL
ARRAY PERFORMANCE

SYSTEM PARAMETERS

ARRAY SIZE:	1 OMNI-HYD	
SOURCE LEVEL VALUE:	0060.00	DB
LOSS TABLE #:	0001	
NET NOISE FIELD #:	0003	
ARRAY PATTERN #:	0116	
DELAY ANGLE:	0010.00	DEG
SEPARATION:	0000.30	FT
LAMBDA:	0001.00	FT
EFFECTIVE NOISE LEVEL:	-0020.00	DB

RANGE NM.	S/N DB.	SIGNAL LEVEL DB.
0050	-0010.81	-0030.81
0048	-0011.77	-0031.77
0046	-0010.83	-0030.83
0044	-0010.83	-0030.83
0042	-0011.63	-0031.63
0040	-0010.88	-0030.88
0038	-0010.75	-0030.75
0036	-0010.33	-0030.33
0034	-0010.18	-0030.18
0032	-0009.37	-0029.37
0030	-0009.60	-0029.60
0028	-0009.95	-0029.95
0026	-0010.15	-0030.15
0024	-0010.45	-0030.45
0022	-0011.88	-0031.88
0020	-0011.02	-0031.02
0018	-0004.07	-0024.07
0016	-0003.32	-0023.32
0014	-0002.32	-0022.32
0012	-0001.47	-0021.47
0010	0000.25	-0019.74
0008	0000.30	-0019.69
0006	0001.58	-0018.41
0004	0003.87	-0016.12
0002	0006.46	-0013.53
0000	0008.33	-0011.66

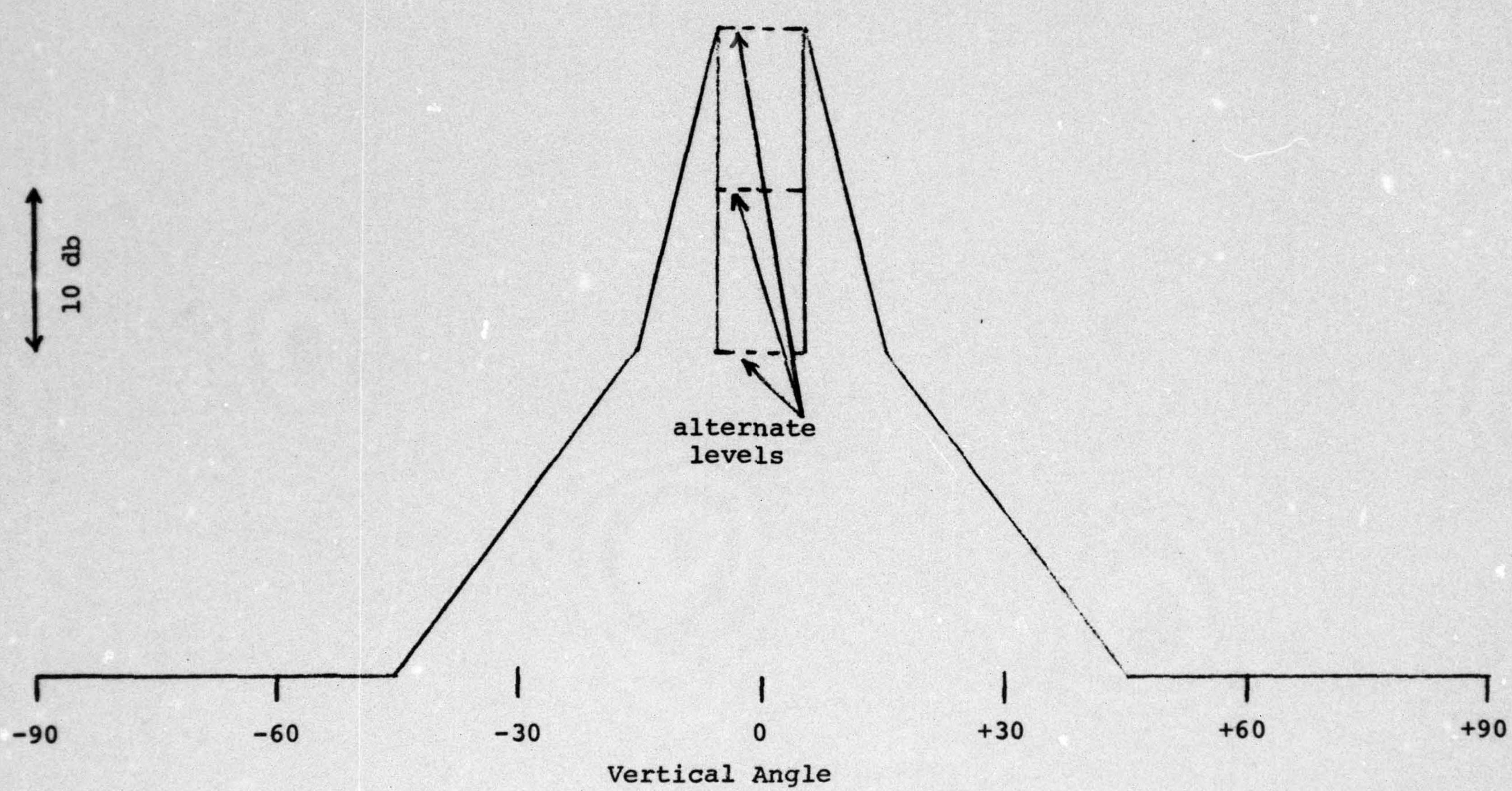

Figure (1)

Sample curves of the vertical directionality of noise in db/steradian as a function of vertical angle.

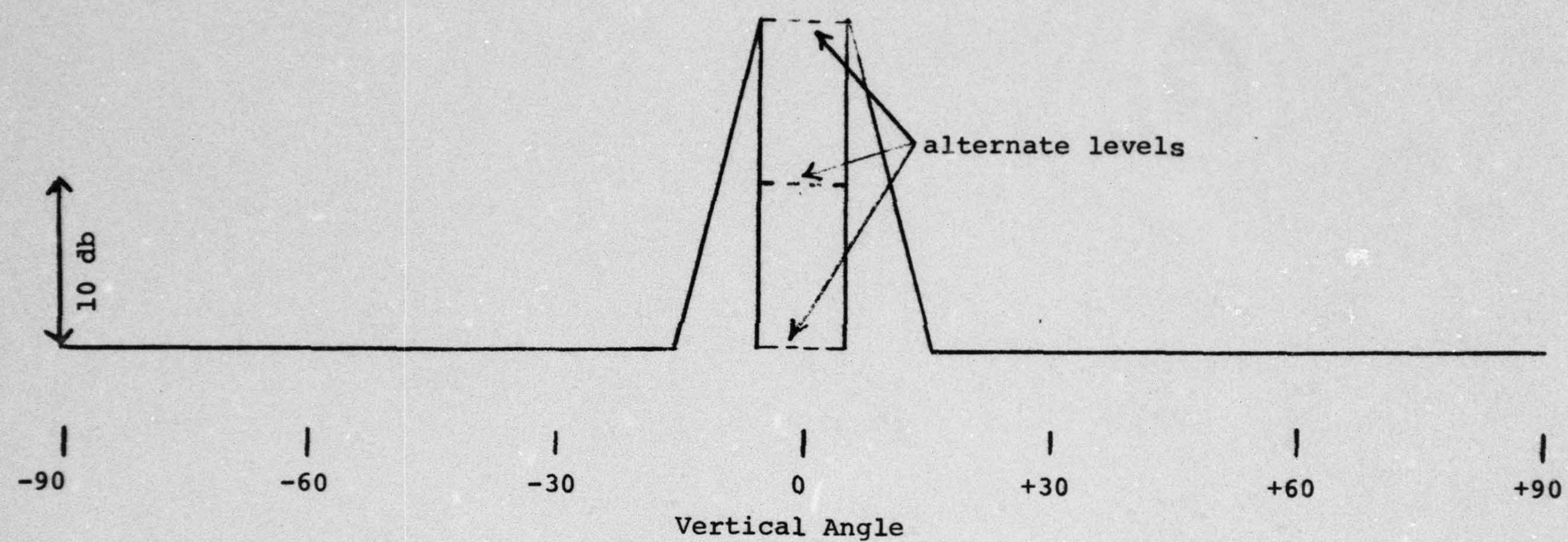

Figure (1) Continued

References

1. C. G. Bassett and P. M. Wolff, "Fleet Numerical Weather Central Bottom Loss Values", Fleet Numerical Weather Central, Propagation Loss Report #2, Technical Note 58, August 1970, CONFIDENTIAL.

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